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Control of Chaotic States in DP Machine Plasma by Using External Circuit Elements

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We present a simple, effective and low-cost experimental method to control chaos in a DP-machine plasma. By using a capacitor, we can substitute the low-frequency chaos (uncorrelated oscillations), which appears in the S-type negative differential resistance region of the static I-V characteristic, by a nonlinear oscillation, the frequency of which is controlled by the external capacitance.

1. Introduction

Control of chaos is one of the most important problems of nonlinear physics [1]. In plasma physics a great interest exists in this subject [2,3], especially in the view of controlled fusion projects.

It is well known [4,5] that under certain experimental conditions in the front of a positively biased electrode immersed into plasma, a complex space charge configuration (CSCC) in form of an electrical double layer (DL) can appear. The static I - V characteristic of the electrode shows at least two regions of negative differential resistance, one S-type and one N-type. The S-type negative differential resistance is related to the appearance and disappearance of a CSCC [4,5], whereas the N-type negative differential resistance is related to the spatio-temporal dynamics of a CSCC [6,7], or to the onset of a low-frequency instability [8]. Between these two regions uncorrelated low-frequency oscillations with a continuous spectrum can appear. Since the oscillations are not correlated, the plasma enters a chaotic state. To avoid this we have inserted a capacitor between the electrode and the ground. In this way a regular oscillatory state supersedes the chaotic one. The frequency of the observed oscillations depends on the time constants of the capacitor.

2. Experimental results and discussion

The experiments were performed in the DP machine of the University of Innsbruck, which was described elsewhere [9]. The plasma, created in the source chamber, was pulled away from thermal equilibrium by gradually increasing the voltage applied to a tantalum disk electrode with 2 cm diameter. The argon pressure was $p = 5 \times 10^{-3}$ mbar and the plasma density $n = 10^{10}$ cm $^{-3}$. At a certain value of the potential on the electrode a quasi-spherical luminous CSCC, confined by a space charge DL, appears in front of the electrode. Fig. 1a and 1c shows the current oscillations through the electrode and the FFT of these, respectively, recorded after the appearance of the CSCC. To characterise these oscillations, we present the autocorrelation function (Fig. 1e) and the reconstructed state space (Fig. 1g). From these figures we conclude that the oscillations are not corre-

lated, giving rise to a low-dimensional chaotic state. By introducing a capacitor into the external electronic circuit between the electrode and ground, we obtain a new oscillation [10], the period of which is determined by the charging and discharging time constants of the capacitor. Fig. 1b, 1d, 1f and 1h show the time series, the FFT, the autocorrelation function and the reconstructed state space, respectively, corresponding to these new current oscillations.

Because of the strong nonlinearity of the CSCC, the noise, which is permanently present in the system, can induce some uncorrelated oscillations of the current, corresponding to jumps of the structure between various unstable states, characterised by different electric conductivities. Usually it is very difficult to control the noise level experimentally. An alternative is to substitute the chaotic dynamics by a periodically one and to control its dynamics by the frequency of the oscillations. This is the method, which also we use. As described above, the periodical state is obtained by inserting a capacitor into the external electrical circuit. In this way we can control the dynamics of the CSCC by modifying the capacitance of the capacitor.

3. Conclusion

We propose a simple, effective and low-cost method to control chaos in a DP-machine plasma. The method permits the substitution of a chaotic state (uncorrelated low-frequency oscillations) by a periodical one, the frequency of which can be easily controlled. For this we only need a capacitor.

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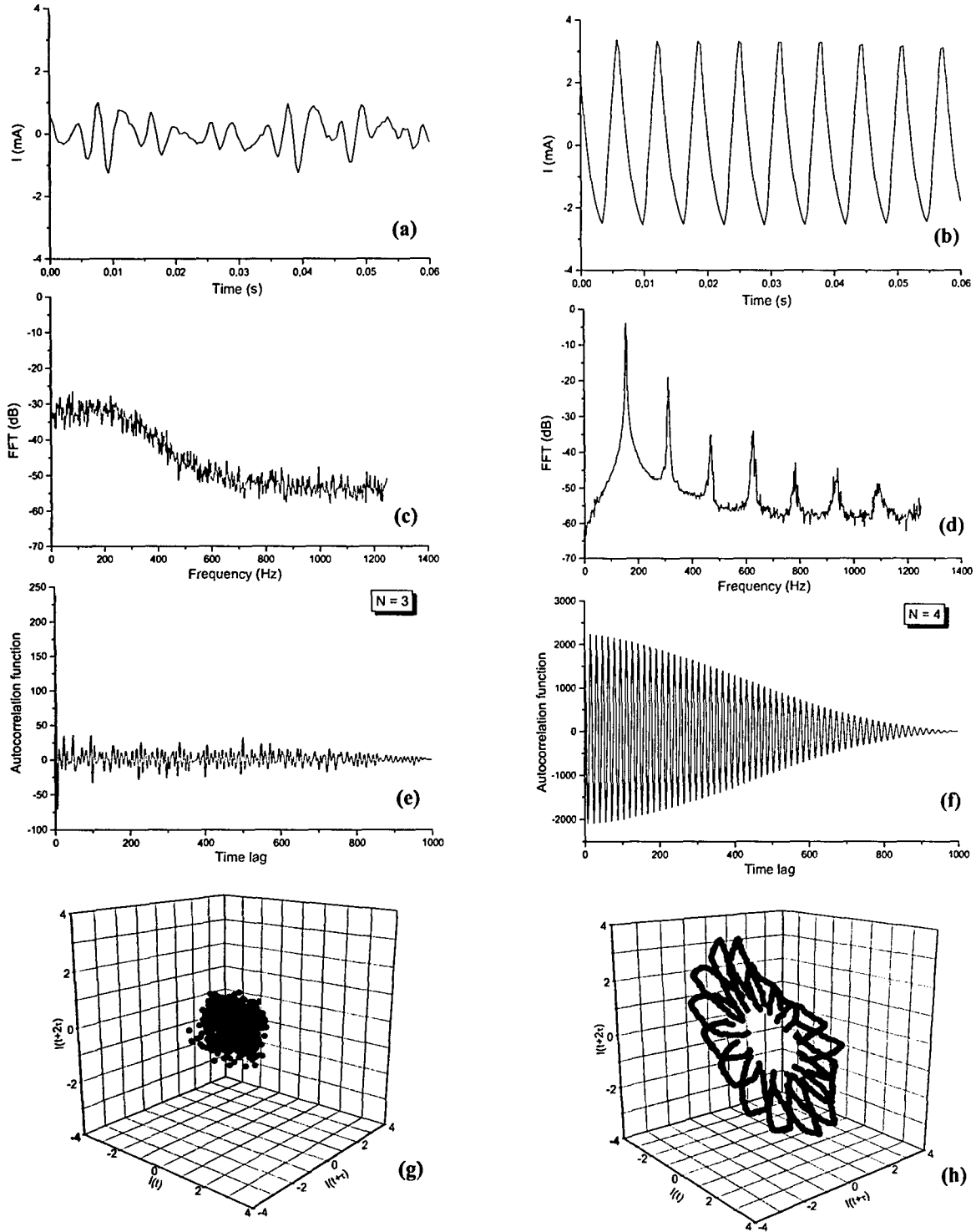


Fig. 1: Time series, FFT, autocorrelation function and reconstructed space of the current oscillations, respectively, before (left column) and after (right column) insertion of a capacitor.